

THE INTELLIGENT CHARGING PATH PLANNING FOR ELECTRIC VEHICLE

ZHI-PING LIN, HER-SHING WANG & SHAO-JYUN TSAI

Department of Industrial Engineering and Management, National Taipei University of Technology, Taipei, Taiwan

ABSTRACT

Due to the problem of global warming continued to increase, in order to reduce emissions of greenhouse gases, so that all countries will be focusing its attention in the automobile industry. Reducing carbon emissions by production of electric vehicles is undoubtedly a big feasible solution. Therefore, vehicle manufacturers develop high-performance electric vehicles, but the related infrastructure of electric vehicles is not perfect, affecting people to buy electric vehicles. Such as insufficient number and non-uniform distribution of the charging station, and the charging waiting time is too long etc., resulting in electric vehicle driver range anxiety. By integrating the charging station information, electric vehicles information and road information that drivers can immediately know the information above. And you can reduce the electric vehicle driving mileage anxiety, improving customer acceptance of electric vehicles. The main purpose of this study is to explore the path planning, in order to solve the same time the complex genetic algorithm vehicles assigned to the complex problem of the charging dock. To consider the electric vehicle charging stations through total traveling time of arrival destination, and the waiting time and the charging time in the charging station, through genetic algorithms calculated optimal charging station selection reduce electric vehicles driving mileage anxiety, and thus to enhance the electric willingness to buy vehicles, prompting electric vehicle can be more popular.

KEYWORDS: Electric Vehicle, Path Planning, Genetic Algorithm

Original Article

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INTRODUCTION

Research Background and Motivation

Development of Battery Electric Vehicle (BEV) for fossil fuel consumption and exhaust emissions is a very possible solution, but the current penetration of electric vehicles is still not high, relatively build infrastructure and incomplete, for example lack of charging stations (CS), the battery exchange stations and other equipment, resulting in the promotion of Battery Electric Vehicles (BEV) more difficult to implement. Electric vehicle drivers are not familiar with the electric vehicle state of charging (SOC), or the location of only a handful of charging stations, energy management of these uncertainties led to a so-called range anxiety. Other words, the availability of Battery Electric Vehicle (BEV) charging facilities directly related to the range anxiety and charging process spends the sum of time (Boulanger et al., 2011). More importantly, when we focus on market penetration of electric vehicles, must pay more attention to the battery itself due to many variations, such as battery capacity, battery life, battery cost, and most important security problem is essential to be carefully considered. In addition to, electric vehicle technology in security and availability, the driver behavior patterns and the availability of charging stations also play an important role (DeVault, 2011).

Research Purposes

For this study, combined with the current rapid development of mobile devices and the cloud network technology. Build a complete charging guidance support system, ensure that convenience and stability of the electric vehicle users to provide accurate information and real-time charging guidance system to solve the electric vehicle driving trip anxiety. The above said, the research purpose of this study are summarized as follows:

- **Minimize the Total Travel Time**

The total travel time including the start point to the travel time of the charging station, waiting for the completion of charging the vehicle in front of the waiting time, the time required for charging and charging station from time to reach the destination of departure. Based on customer input destination, estimated remaining battery can travel distances, and find out charging station through algorithms can be use the remaining power of the search range, allowing to minimize the total travel time of charging stations, electric vehicles to the guide charging station for charging.

- **Improve the Utilization of the Charging Station**

The algorithm used in this study can reduce waiting time to charge electric vehicles, assigned want to charge electric vehicles to more free charging stations, to avoid waiting a single charging station charging excessive number of vehicles, and assign them to wait for vehicle charging station to charge less, achieve their goals to improve the utilization of the charging station.

LITERATURE REVIEW

Genetic Algorithm

Genetic algorithms is an optimal algorithm for simulation program of biological evolution, the concept of the algorithm is similar to Darwinian natural selection, through the mechanism of evolution to keep the better individual and to retire unsuitable individuals, during countless generations after evolution, we can get the optimal goals.

After Holland (1975) proposed genetic algorithm, his students applied it to transmit gas pipeline, after they proved genetic algorithms extremely extensive, genetic algorithms became popular, there were many scholars in various fields to explore each type problems and the use of genetic algorithm to fine the optimal solution.

If using genetic algorithms to solve the optimal problem, we must target for the problem first, find the corresponding fitness function (Fitness Function), and generates the initial solution. With the chromosome fitness, a collection of groups, the chromosome was said to be the population including through the evolution of reproduction, crossover, and mutation, produce offspring repeatedly iterate evolve and produce next-generation solutions.

Now, genetic algorithm is widely used in various fields to explore relevant literature, and there are many examples of genetic algorithm combined with genetic algorithms or other algorithms modification to obtain better results, such as Liu et al. (2013) genetic algorithm and tabu search method combined, vehicle scheduling problem solving family caregivers encountered, which is considered a special vehicle routing problem, the result appears in the effective time can provide a good solution. (Lau et al., 2010) the standard genetic algorithm combined with fuzzy concept to solve the multi-depot, multi-product vehicle routing problem, and the final standard genetic algorithms, simulated annealing, tabu search wears comparison and found that genetic algorithm plus defuzzification algorithm is the most outstanding.

MODEL CONSTRUCTION

Problem Definition and Hypothesis

- Vehicle speed provided by the arrival time basis, and will not be affected by the emergency and other conditions.
- There are five models of electric vehicles, each vehicle has a different life from the time required for charging.
- Charging station located in four north counties 102 charging stations, each charging stations have three available charging cradle.
- Work rates of all charging stations are the same, not because of human and mechanical reasons so that the charging process time instability.
- Appointment charging time will not be a single plug.

Study Framework

This study will be divided into two stages of its framework, each stage described in detail below:

- **The First Stage**

Refer to the relevant literature and the actual use of the market with electric vehicle charging station application software, understand the difficulties on the current status of the electric car and practical applications experience, and to identify the shortcomings of existing software to analyze its strengths and weaknesses, and be absorbed and improvement, develop a new mode of operation of the charging station navigation software, we can improve the existing software can not complete functionality.

- **The Second Stage**

The study of electric vehicles assigned to the charging station problem belongs to regional distance planned change of planning open vehicle distance, therefore joined the remaining power restrictions, and restrictions on the charging time of the establishment of mathematical models and consider the idle weight of the charging station, so a high vacancy rate of charging stations can more easily be assigned. Heuristic algorithm to assign the vehicle to the optimum charging station for charging, charging stations reach while meeting the needs of operators and users, promote the upgrading of the electric vehicle penetration.

Construction of Mathematical Models

This study aims to build an electric vehicle charging to meet demand, and total travel distance to reach the minimum objective, as well as to enhance the utilization of the charging dock, charging to improve the overall quality and efficiency, digestion journey anxiety, symbolic variables are as defined in this study listed in Table 1.

Table 1: Symbol Definition and Description

| Symbol | Definition Description |
|--------------------|--|
| Serial Number | |
| i | Electric Car No. $i \in \{1, 2, \dots, P\}$ |
| j | Charging stand No. $j \in \{1, 2, \dots, Q\}$ |
| k | Electric Car types $k \in \{1, 2, \dots, 3\}$ |
| Parameters | |
| M_{ij} | Electric Car i origin and Charging stand j 's distance |
| F_{ij} | Electric Car i end and Charging stand j 's distance |
| W_{ij} | Electric Car i at Charging stand j 's waiting time |
| C_{ij} | Electric Car i at Charging stand j 's charging time |
| S | Travel rate |
| T_{ik} | Electric Car i are types k |
| B_k | The maximum travel distance of the types k 's battery |
| SOC_i | The Percentage of power remaining of the electric Car i |
| Decision Variables | |
| X_{ij} | 1 • Electric Car i be assigned to Charging stand j 0 • else |
| Y_{ij} | 1 • Electric Car i at Charging stand j can be filled 0 • else |
| Z_i | 1 • Electric Car i can accept not to be filled 0 • else |

- Objectives Formula

$$\text{Min TTT} = \sum_i^m \sum_j^n \left\{ X_{ij} \left[(M_{ij} + F_{ij}) \times \frac{1}{S} + W_{ij} + C_{ij} \right] \right\}$$

- Constraint

$$\sum_i^m \sum_j^n X_{ij} = 1$$

$$SOC_i \times B_k - M_{ij} \geq 5$$

$$Z_i + Y_{ij} \geq 1$$

$$\frac{-(SOC_i \times B_k) - M_{ij}}{200} \times 30 \geq C_{ij} \geq 5$$

$$F_{ij} \leq B_k$$

$$SOC_i \times B_k - M_{ij} + \frac{C_{ij}}{30} \times 200 > M_{ij}$$

$$Y_{ijk} \in \{0,1\} \cdot X_{ijk} \in \{0,1\} \cdot Z_k \in \{0,1\}$$

$$\forall i, \forall j$$

$$(3.1)$$

$$\forall i, \forall j, \forall k \quad (3.2)$$

$$\forall i, \forall j \quad (3.3)$$

$$\forall i, \forall j, \forall k \quad (3.4)$$

$$\forall i, \forall k \quad (3.5)$$

$$\forall i, \forall j, \forall k \quad (3.6)$$

$$\forall i, \forall j, \forall k \quad (3.7)$$

- **Formula Description**

- (3.1) The same vehicle can only be assigned to a charging station.
- (3.2) After the traveling distance of the charging stations can be subtracted from the distance of the remaining battery of the electric car must be greater than 5 km
- (3.3) Don't let full of vehicles be assigned to the charging station which can't be filled.
- (3.4) Charging time is at least more than 5 minutes and less than full time battery.
- (3.5) Charging station distances destination that must be less than the EV_i maximum travel distance.
- (3.6) After charging the battery must be able to reach their destinations.
- (3.7) Y_{ijk} , X_{ijk} , Z_k are all 0 or 1 decision variables.

IMPLEMENTING AND CASE ANALYSIS SYSTEM

Case Analysis and Evaluation

In this study, simulation and analysis of the way, prove the feasibility and performance of the system established in this study, experimental methods for the use of the system and (1) the shortest distance method: Select the nearest charging station for charging; (2) The minimum completion time method (Hsieh, 2014): the shortest time required to complete the charge charging stations, and the two methods were compared.

This study simulated 12 hours of vehicle operation. Case I circumstances demand charge per minute for six. Case II, compared with per minute for 8, the remaining charge of 15-40%, the vehicle's car models appear randomly selected from five different models of electric vehicles, the maximum cruising range each 140,160,260,380,450 km, 102 charging stations located in four counties New Taipei City, Taipei City, Keelung City, Taoyuan City charging stations each have three charging cradle, charging a rate of 55km / 10min, each method are required to run 30 times its average.

Case I

This problem will occur every minute demand mode vehicles increased to six, it appeared 12 hours total 4320 charge guide demand. Figure 1 shows the use of the system still has the shortest total travel time. The minimum charge

completion time method of charging completion time is the earliest, but the average time of arrival plus charging stations charging station to the destination time average is higher than the present study approach.

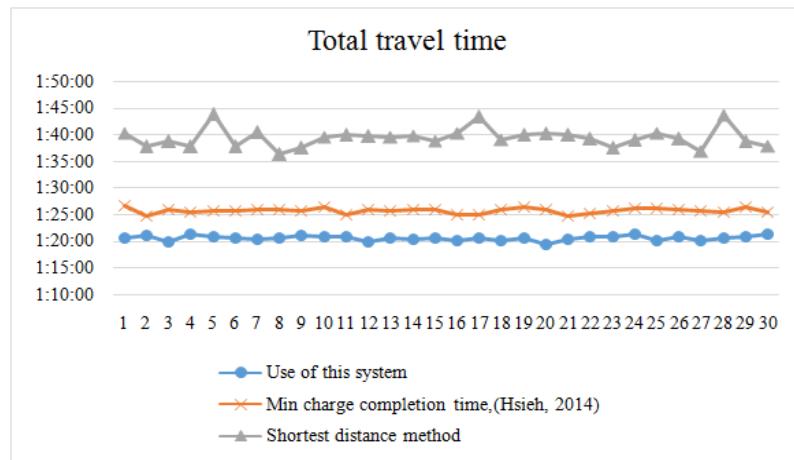


Figure 1: Scale Analog 1 of Data

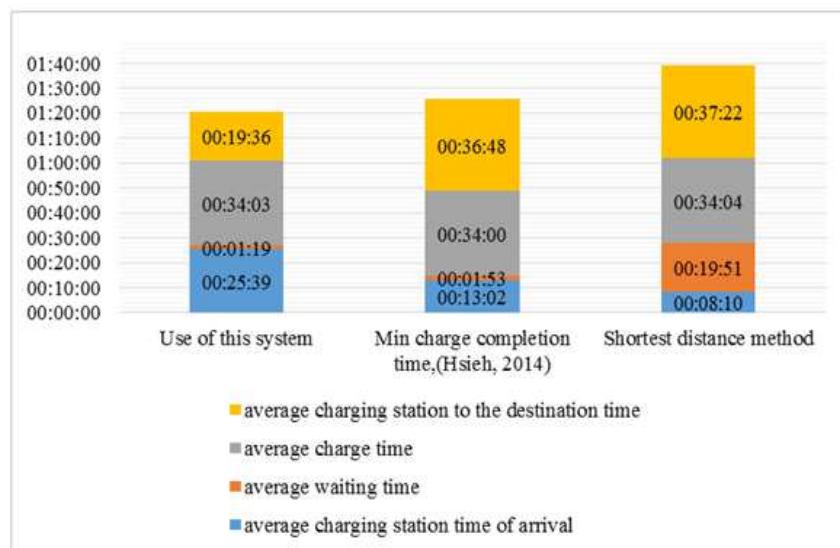
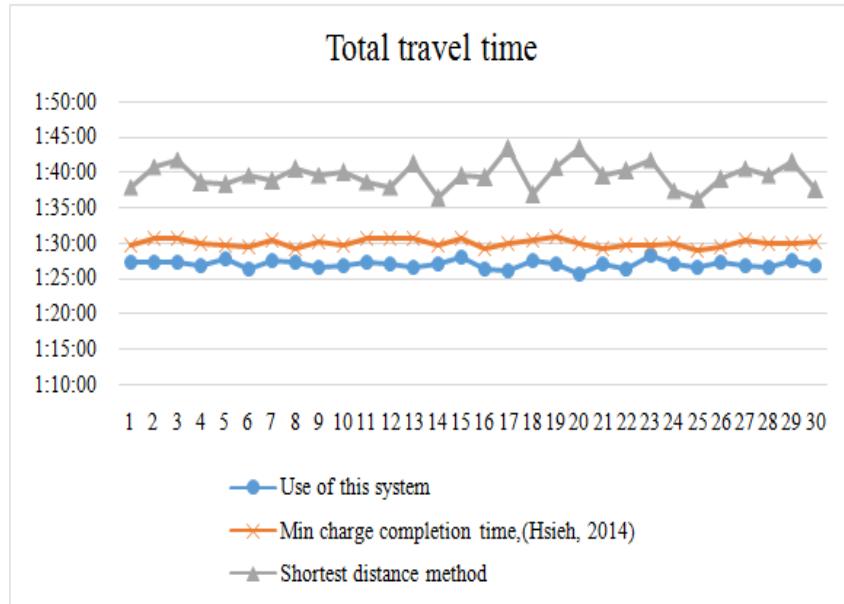
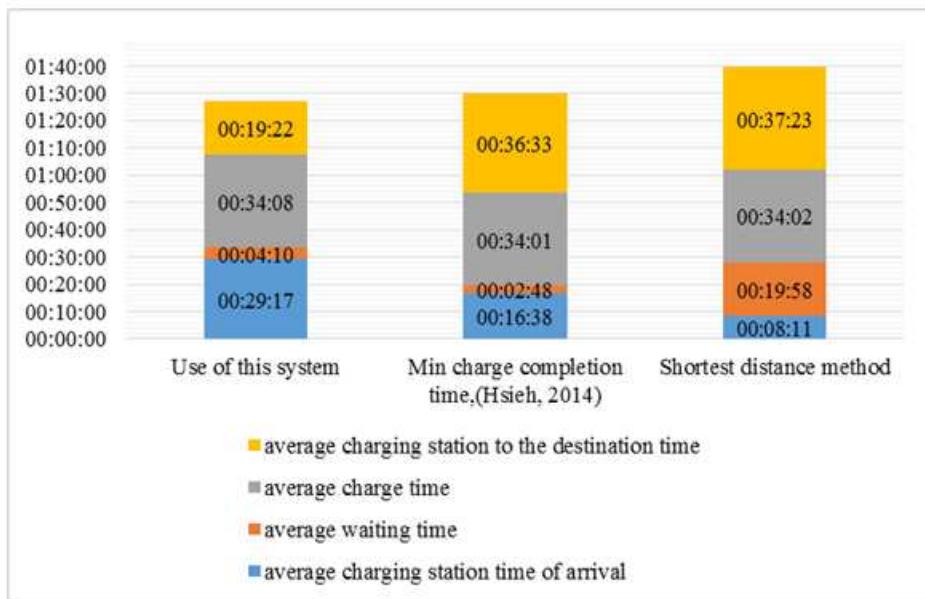


Figure 2: Average Time Scale of 2 of the Individual Stack Diagram

Case II

This problem will occur every minute demand mode vehicles increased to eight, a total of 5760 units. Due to the number of users to enhance waiting time using the system and the total travel time significantly increased, it can be deduced that size is close to the upper limit of the number of services, if we increase the number of users will result in long waiting periods.

**Figure 3: Scale Simulation of the Data****Figure 4: Average Time Scale of 2 of the Individual Stack Diagram**

CONCLUSIONS AND SUGGESTION

The primary results of this study have achieved the goals ; minimize the total travel time and improve the utilization of the charging station.

The suggestion of the future study will be considered the demand is not fixed. Setting peak and off-peak charging time can not only improve the reality of the system, but also let the grid power dispatch in a certain planning.

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